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13. ABSTRACT *(Maximum 200 words)*
THIS TEST PLAN HAS FIVE SEPARATE OBJECTIVES. THE FIRST OBJECTIVE IS TO EVALUATE THE EFFECTIVENESS OF THE PRESENT PILOT CONTAINMENT SYSTEM TO INTERCEPT, TREAT, AND REINTRODUCE CLEAN WATER INTO THE AQUIFER. THE SECOND OBJECTIVE IS TO DEFINE STEADY-STATE OPERATING CONDITIONS FOR THE PRESENT PILOT CONTAINMENT SYSTEM. THE THIRD OBJECTIVE IS TO EVALUATE THE EFFECTIVENESS OF A HYDROLOGIC EXTENSION TO THE PRESENT PILOT CONTAINMENT SYSTEM. THE FOURTH OBJECTIVE IS TO COMPARE FIELD OPERATION AND THEORETICAL PERFORMANCE OF THE SYSTEM. THE FIFTH OBJECTIVE IS TO PREPARE A TECHNICAL REPORT OF RESULTS.

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DEPARTMENT OF THE ARMY
ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO 80022

82160R15
ORIGINAL

SARRM-TOE-C

7 Feb 79

SUBJECT: Testing of the Pilot Containment System

Commander
US Army Toxic & Hazardous
Materials Agency
ATTN: DRXTH-IR (Don Campbell)
Aberdeen Proving Ground, Maryland 21010

1. Reference is made to FONECON, 20 Dec 78, between Dr. John Wardell, Contamination Migration Branch, and Mr. Don Campbell, USATHAMA.

2. The draft test plan is inclosed for your review and comment. As a result of reference, it was prepared in accordance with your Format Guidelines for Preparation of IR Decontamination Technology Test Plans.

FOR THE COMMANDER:

1 Incl
as

Irwin M. Glassman
IRWIN M. GLASSMAN
Director of Technical Operations

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TESTING OF THE PILOT CONTAINMENT SYSTEM
(ITARMS TASK NO. 1.05.31)

by

J. F. WARDELL
CONTAMINATION MIGRATION BRANCH
TECHNICAL OPERATIONS
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PREPARED FOR:

Commander
US Army Toxic & Hazardous
 Materials Agency
ATTN: DRXTH-IR (Don Campbell)
Aberdeen Proving Ground, Maryland 21010

FEB 79

TESTING OF THE PILOT CONTAINMENT SYSTEM

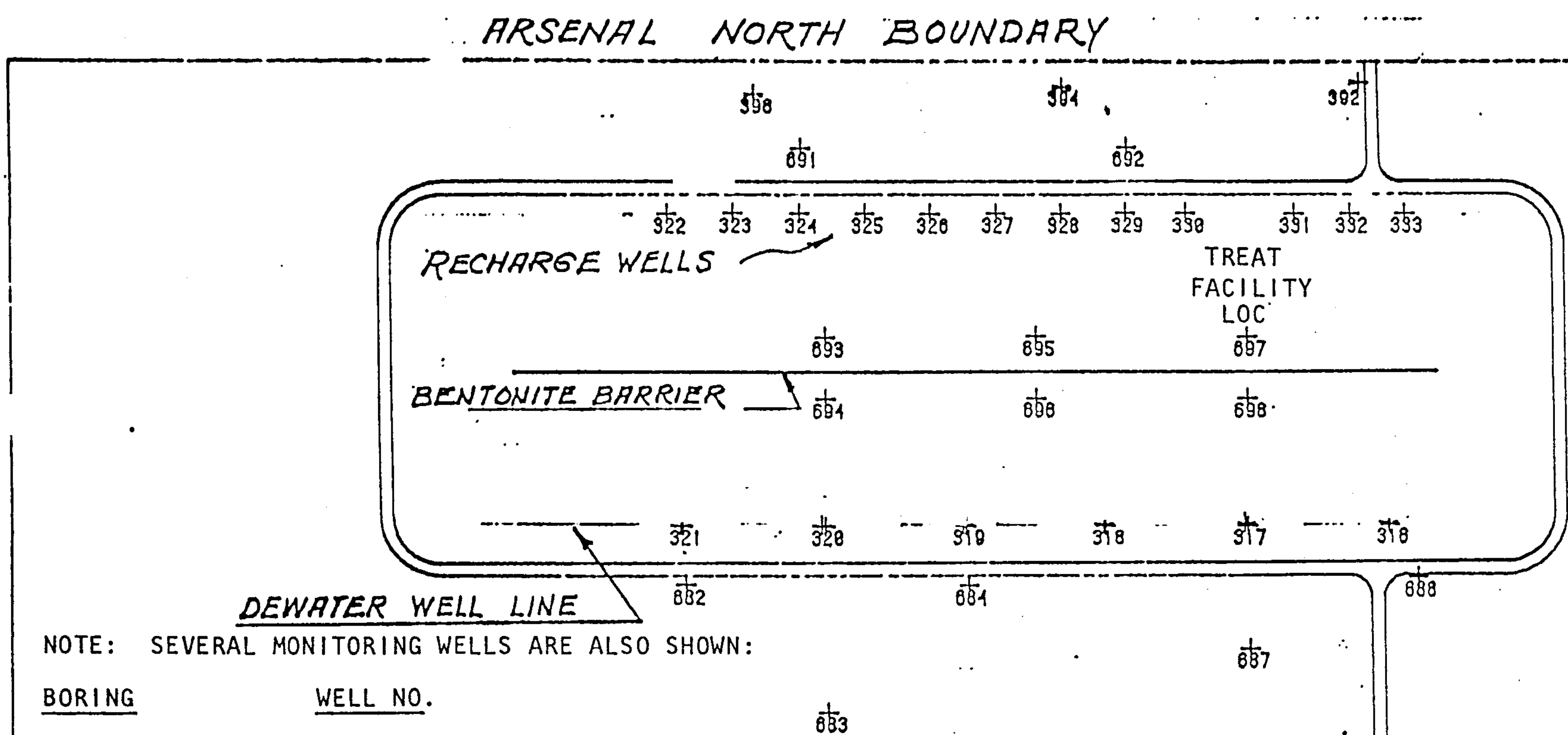
1. Introduction

a. In late Jul 78, operation of a pilot containment system was begun. It was located at the northern boundary of Rocky Mountain Arsenal (RMA). This system was constructed to show that the Department of the Army (DA) intended to comply with the Cease and Desist Orders issued by the Colorado Health Department against RMA (representing DA) and Shell Chemical Company (SCC) to halt discharge of two pollutants (DIMP and DCPD) off post. The Cease and Desist Orders were issued in Apr 75.

b. The pilot containment system consists of: (1) Dewatering wells, (2) Pollutant removal facility, (3) Recharge wells, (4) Physical barrier between the dewatering and recharge wells, and (5) Monitoring wells. Contaminated water is removed from the aquifer by dewatering wells, treated by passing through the pollutant removal facility (granular carbon column), and reintroduced into the aquifer by recharge wells. The physical barrier minimizes possible failure of the total system. It prevents treated water from flowing back into the area of the dewatering wells, ensuring that only contaminated water is passed through the removal facility and holds polluted water in the area of the dewatering wells so that the maximum amount of contaminated water can be treated by the removal facility (Figure 1).

c. The pilot containment system does not intercept the entire plume of polluted water crossing the northern Arsenal boundary. It was designed to evaluate the feasibility of this type of containment configuration to intercept, treat, and reintroduce groundwater into an aquifer. Consequently, an extension is required to this existing structure to treat all polluted water leaving the north part of RMA. Data gathered from operation of the pilot system would be used to assist design of the expanded containment system.

d. Prior to construction of the pilot containment system, two possible system configurations were evaluated. One configuration was a hydrologic system, and the other was the previously described physical barrier system. The hydrologic system lacks the physical barrier between dewatering and recharge wells. The physical barrier system was selected for the pilot containment system because it maximized the potential for success.



NOTE: SEVERAL MONITORING WELLS ARE ALSO SHOWN:

BORING	WELL NO.
392	23-43
394	45
396	47
691	110
692	111
693	112
694	113
695	114
696	115
697	116
698	117
682	118
683	119
684	120
687	123
688	24-56
154	7

FIGURE 1. PILOT CONTAINMENT SYSTEM

2. Objectives - This test plan has five separate objectives. The first objective is to evaluate the effectiveness of the present pilot containment system to intercept, treat, and reintroduce clean water into the aquifer. The second objective is to define steady-state operating conditions for the present pilot containment system. The third objective is to evaluate the effectiveness of a hydrologic extension to the present pilot containment system. The fourth objective is to compare field operation and theoretical performance of the system. The fifth objective is to prepare a technical report of results.

3. Approach

a. The test plan encompasses four areas: (1) Evaluate the effectiveness of the existing pilot containment system to remove pollutants from groundwater, (2) Determine operating parameters for steady-state operation of the present system, (3) Evaluate the effectiveness of a hydrologic extension to the existing system, and (4) Determine the "goodness of fit" between theoretical operation of the facility well subsystems and field operation.

b. To accomplish the first objective, operation data is being collected at predetermined time periods for the pilot containment system. Plant operating conditions and chemical composition of water entering and leaving this system is being determined.

c. The following procedure is being used to determine steady-state operating procedures of the existing pilot containment facility.

(1) The groundwater flow rate is estimated for the cross-sectional area occupied by the existing containment system before and after installation.

(2) The system operating conditions required to achieve the steady-state flow rate of the natural aquifer are calculated.

d. To evaluate the effectiveness of a hydrologic extension, contractual computer simulation techniques are being used.

e. To accomplish the fourth goal, a study is being initiated to compare field responses and theoretical calculations for the well subsystem of the pilot containment system.

4. Methodology

a. Subtask 1 - Evaluate the Effectiveness of the Pilot Containment System to Remove Pollutants from Groundwater

(1) The purpose of this Subtask is to analyze data from the pilot containment system to determine the effectiveness to remove pollutants from groundwater.

(2) Scope

(a) The pilot containment system was constructed to evaluate the ability of a system configured in that manner to remove polluted water from an aquifer, remove pollutants from the water, and return clean water to the aquifer. This sytem would be considered successful if: (1) Treated groundwater met applicable groundwater quality standards and (2) Groundwater flow was not adversely changed from natural aquifer conditions.

(b) The performance of the pilot containment system is being monitored to evaluate its operation. The chemical composition of contaminated groundwater entering the treatment facility and leaving the facility is being determined. The quantity of groundwater entering and leaving the treatment facility is also being recorded. The chemical analyses are performed by the Analytical Systems Branch, RMA, or USGS using previously approved procedures.

1 Several chemical constituents are to be evaluated daily. These constituents indicate the effectiveness of the system to control off-post migration of pollutants or those required to monitor plant operational performance. These constituents are DIMP, DCPD, Nemagon, CMPSO, CPMO2, Oxathiane, Dithiane, and Fluoride; and pH, conductivity, TOC, and TSS, respectively.

2 Several chemical constituents are to be evaluated weekly. They indicate the effectivness of the pilot containment system to treat other RMA-related compounds for which the facility was not specifically designed to handle. These constituents are Aldrin, As, Cl, Dieldrin, Endrin, Hg, Isodrin, Na, Nitrate, DDE, DDT, and Sulfate.

3 A few chemical contituents are to be evaluated monthly. These constituents provide information to further evaluate overall plant operations. They are not of concern as groundwater pollutants. Examples of this type of constituent are Cu, Fe, Mn, Mg, and Sodium Nitrate.

4 Volumes of groundwater removed from the aquifer and reintroduced into the aquifer are determined on a weekly basis.

5 Plant operating parameters are measured for each month. Examples of these parameters are inlet and outlet pressures, sump reading, sump setting, flow reading, and flow pressure. The range, mean, and standard deviation of each measurement during the month is reported.

6 On- and off-post well water samples are collected to evaluate groundwater quality up and downstream of the treatment facility. The 360° monitoring program constituents are measured. A total of 30 wells (three off post) are part of the program. These wells should detect groundwater quality changes as a result of operation of the pilot containment system. The wells have been subdivided into four groups -- a group of wells are sampled normally each week.

(c) Reports

1 Data collection forms for recording plant operation information are at Appendix 1.

2 Monthly and quarterly summaries of operation of the pilot containment system are sent to USATHAMA, ATTN: DRXTH-IR, by the fifteenth working day of the month. The monthly summary reports plant operation data for the preceeding month and water quality data for the month, two months previous to the report date (i.e., December report contains October data). This delay is due to time required to analyze chemical samples. Water quality data is reported for groundwater entering and leaving the facility and monitoring wells upstream and downstream of the plant (to include off-post wells). The quarterly summary is prepared two months after the end of the quarter being reported (i.e., October through December is reported in February) because of the delay in receiving chemical data.

b. Subtask 2 - Determine Operating Conditions for the Pilot Containment System to Achieve Steady-State Operation

(1) Purpose - The purpose of this Subtask is to define the operating conditions for operating the pilot containment facility at steady-state. Steady-state operation is defined as operating the facility so that groundwater is removed from the aquifer, passed through the treatment facility, and reintroduced into the aquifer at a rate which does not change the rate of groundwater flow off Arsenal from that occurring before construction of the facility.

(2) Scope

(a) A study has been initiated to calculate the flow rate of groundwater through the area occupied by the pilot containment system: (1) Before construction of the facility and (2) After construction of the facility.

(b) To calculate the groundwater flow rate:

1 The cross-sectional area of the saturated aquifer is determined.

2 The hydraulic gradient of the area is determined.

3 The aquifer permeability is estimated.

4 Flow rate is calculated using Darcy's Law:

$$Q = KA \left[\frac{DH}{DL}\right]$$

Q - Flow rate
K - Permeability
A - Cross-sectional area of the saturated thickness
$\left[\frac{DH}{DL}\right]$ - Hydraulic gradient

5 To achieve correct groundwater flow through the pilot containment system, facility operating conditions would be adjusted as required.

(c) The pilot containment system monitoring wells will continue to be observed to determine changes in water levels as a result of system operation. This data is collected as part of the continuous monitoring of overall performance of the containment system (Subtask 1). Well water level changes in conjunction with other data such as pumping rates of dewatering wells and flow rates through recharge wells permit continued steady-state operation of the pilot contaiment system.

1 The wells are divided into four groups. Water-level measurements and water quality are taken for three of the four groups (1, 2, and 3). Water-level measurements only are taken for the fourth group.

2 Group 1: 23-10, 13, 30, 43, 45, 47, 110, 111, 118, 119, 120, 123; 24-7, 20, 56; OP 305, 308, 309 .

Group 2: 23-8, 11, 14, 16, 110, 111; 24-8, 9.

Group 3: 23-9, 12, 15, 110, 111; 24-2, 10, 11.

Group 4: 23-110, 111, 112, 113, 114, 115, 116, 117.

3 Thirty different wells are formally included in the monitoring program; three of them are off-post. Other water level changes are reviewed, as appropriate. Well Groups 1 - 3 are sampled once a quarter. Well Group 4 is sampled each week.

4 Water-level measurements are taken with a steel or electric tape, using the top of casing as the reference point. The water level in the well is determined by subtraction of the tape measurement from the casing elevation.

c. Subtask 3 - Evaluate the Effectiveness of a Hydrologic Extension to the Present Pilot Containment System

(1) Purpose - The purpose of this Subtask is to evaluate the effectiveness of a hydrologic extension to the present pilot containment system. It would be effective if it could remove enough groundwater from the aquifer for treatment so that groundwater crossing the Arsenal boundary meets applicable water quality standards and groundwater flow is not adversely affected.

(2) Scope

(a) To evaluate the effectiveness of a hydrologic extension to the present facility, a computer simulation study will be completed. Waterways Experiment Station, Vicksburg, Mississippi, will be asked to perform the computer modeling. A sample work statement which outlines tasks to accomplish this overall Subtask is at Appendix 2.

(b) The computer simulation approximates actual field conditions at the pilot containment location at RMA because errors cannot be completely eliminated in field data collection. The present facility is being used to provide an idea about the "goodness of fit" of theoretical calculations and observed field results. The dewatering and recharge wells are being subjected to a series of tests. Expected theoretical results are first determined from applicable equations; field observations provide information about actual facility responses.

d. Subtask 4 - Compare Field Operation and Theoretical Performance of the Pilot Containment System

(1) Purpose - The purpose of this Subtask is to evaluate the "goodness of fit" between field operation of the well subsystems and theoretical performance. Completion of this Subtask should provide valuable information to a possible physical barrier extension to the pilot containment system.

(2) Scope

(a) Recharge capacity of a single recharge well will be evaluated for the pilot containment system.

1 The following equation describes radial groundwater flow from a recharge well penetrating into an unconfined aquifer (see Figure 2). Significant changes in recharge of an aquifer occur when the head height is increased above the water table:

$$QR = \pi \; K \frac{\{HW^2 - HO^2\}}{\text{Log N } \{RO/RW\}}$$

QR - Radial flow
π - 3.14
K - Permeability
HO - Aquifer height
HW - Distance from top of water in well to bedrock
Log N - Natural log of RO/RW
RO - Radius of cone of impression where it intersects top of water table
RW - Well radius

2 A recharge well is recharged at different percentages of maximum head height, with the adjacent recharge wells turned off. The different percentages of maximum head height and test wells are selected after initial informal testing of the pilot containment system provides data about the limits of system pumping rates. Approximately one month is required to complete a test with a single head height to ensure stabilization of the recharge well. The data can be used to determine the number of recharge wells required to support a physical barrier extension to the present system.

(b) The cone of depression between dewatering wells and a dewatering well and the bentonite barrier will be determined for the pilot containment system. The observed cones of depression are compared to theoretical performance.

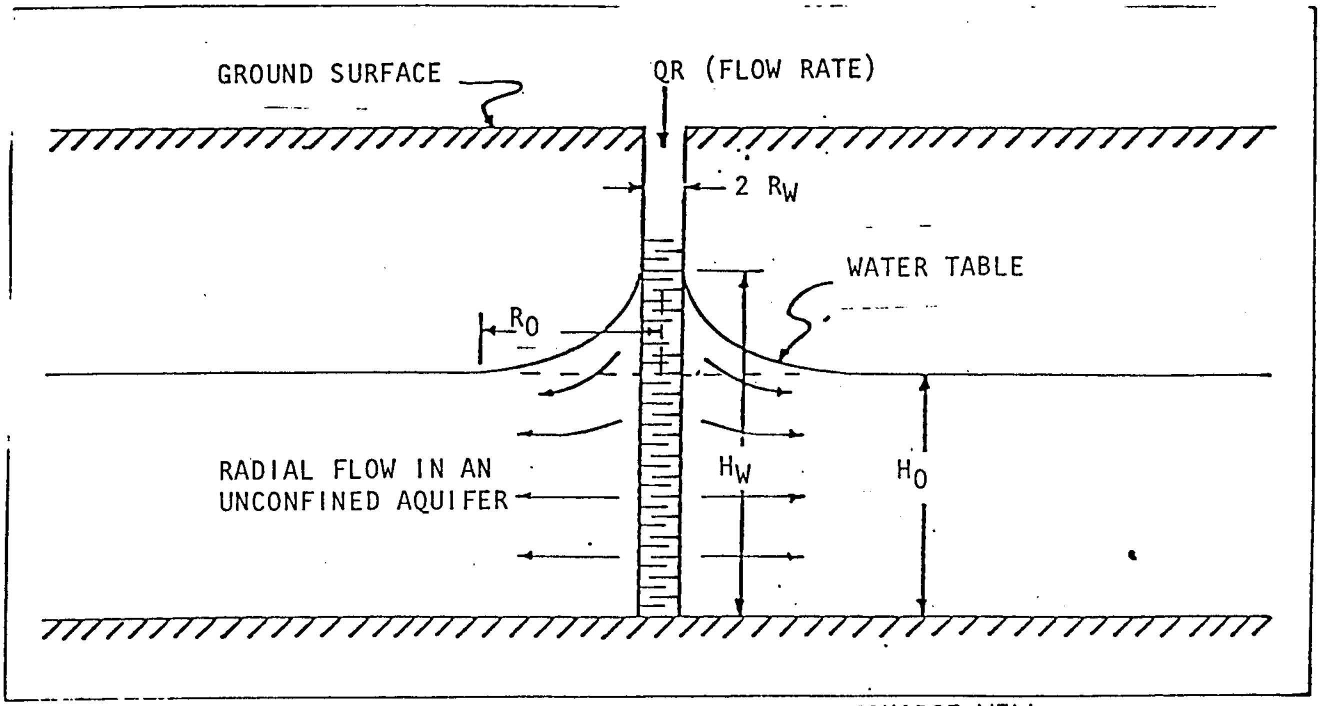


FIGURE 2. RADIAL FLOW FROM A RECHARGE WELL

1 A dewatering well is pumped at different percentages of maximum draw-down rates, while adjacent wells are turned off. Monitoring wells and the adjacent dewatering wells provide data about the cone of depression.

2 The test is repeated, but adjacent dewatering wells are pumped at a constant draw-down rate.

3 Where two or more wells are pumping from the same aquifer and near each other, their areas of influence overlap. Draw-down is the total of the individual draw-downs at that location. Figure 3 shows the individual well (dotted line) and total aquifer draw-down (solid line) curves for three wells in a line, all dewatering at the same rate. The total draw-down curve is determined by adding the individual well draw-down curves at each point of their individual draw-down curves.

4 If a dewatering well is located in the vicinity of a physical barrier, the barrier affects the well draw-down curve because groundwater recharge is restricted. An approach to evaluate the impact is to use the theory of well images (Figure 4). The image of the actual well is placed on the other side of the barrier at the same distance from the barrier as the actual well. A theoretical draw-down curve is developed for both wells using a previously selected constant pumping rate (Y). These cones of depression are the dotted line in Figure 3. The image well cone of depression is the same as the affect of the barrier on the actual well cone of depression. The resultant theoretical cone of depression of the actual well adjacent to the barrier (Y3) is the solid line in the Figure. It is determined by adding the actual well (Y2) and the image well (Y1) cones of depression at each point of their individual cones of depression. The field well is pumped at the same contant pumping rate, and the resultant cone of depression is monitored. The theoretical and actual results are compared.

5 The different percentages of maximum draw-down rates and test wells are selected after initial informal testing of the pilot containment system. Approximately one month is required to complete a single draw-down pumping rate to ensure stabilization of the dewatering well(s).

6 Presently, monitoring wells for dewatering wells are generally limited to the east end of that subsystem. If initial testing of the pilot containment system indicates that best results would be achieved using dewatering wells at the west end of the barrier, several monitoring wells must be drilled.

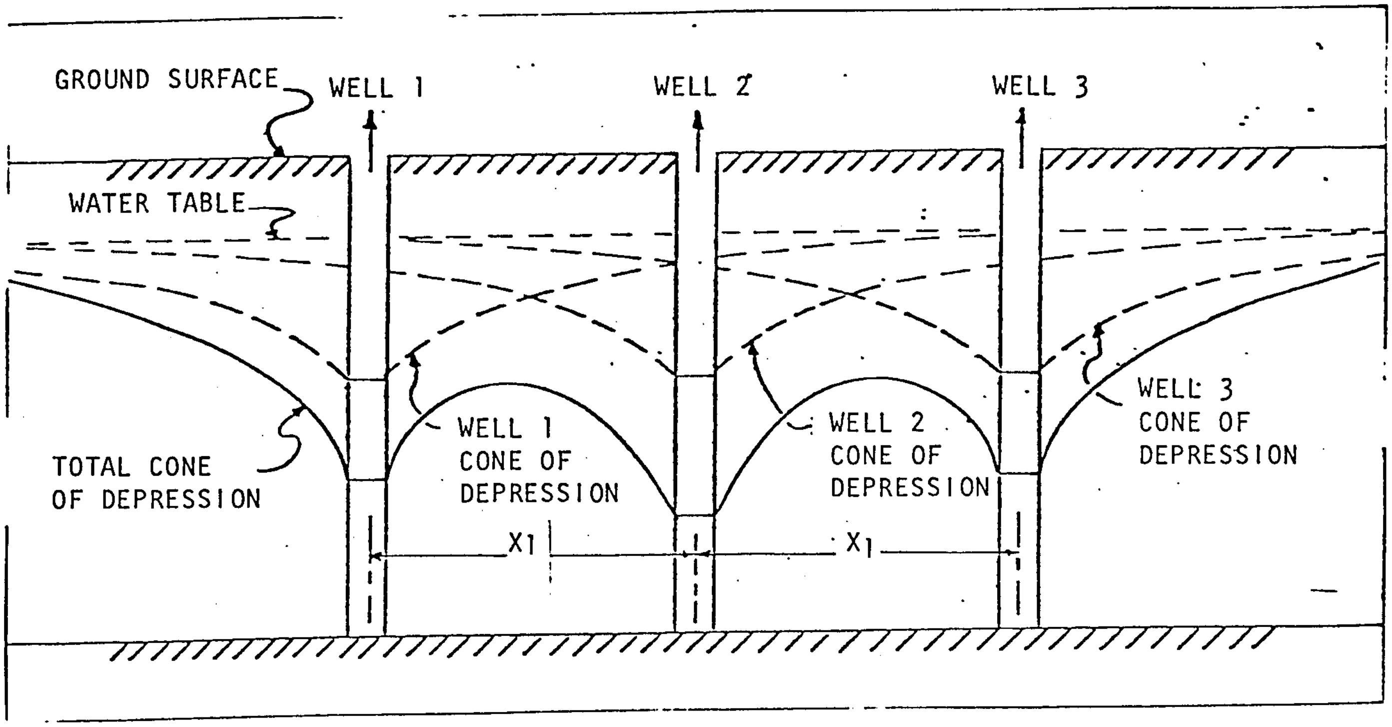


FIGURE 3. CONES OF DEPRESSION FOR A LINE OF WELLS

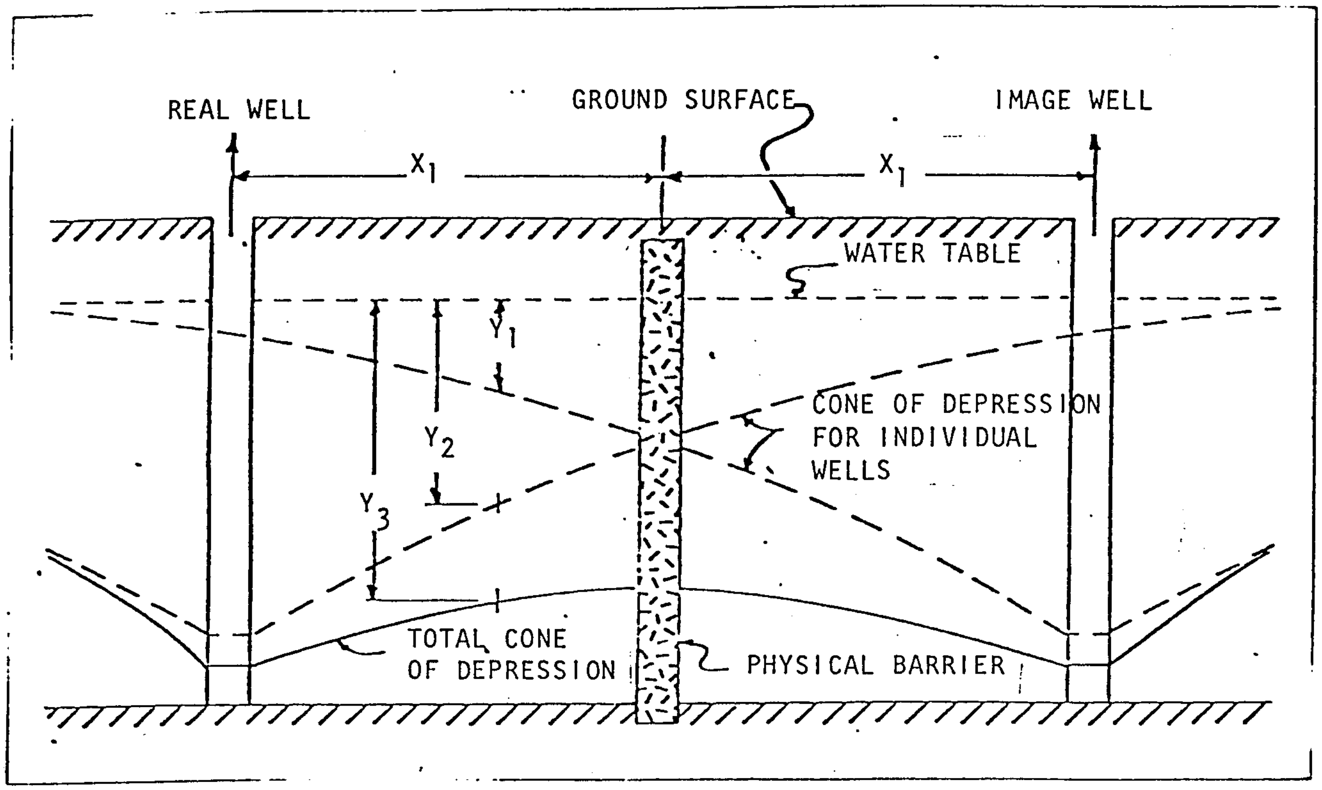


FIGURE 4. THEORY OF WELL IMAGES

e. Subtask 5 - Submission of Technical Report

(1) Purpose - Document findings of this study.

(2) Scope - A technical report will be submitted to the Director, Technical Operations, RMA, with appropriate distribution when the research has been completed and the data analyzed. The report will include: background, objective(s) of the study, results, discussion, conclusions, and recommendations.

5. Schedule - A time schedule for each of the subtasks follow:

a. Subtask 1 - Evaluate the effectiveness of the existing pilot containment system to treat polluted groundwater: On-going. This Subtask is a continuing requirement as long as the facility is operated.

b. Subtask 2 - Determine operating conditions for the pilot containment system to achieve a steady-state operation: Completed by 15 Mar 79.

c. Subtask 3 - Evaluate the effectiveness of a hydrologic extension to the present pilot containment system: The computer simulation study (work statement at Appendix 2) was to be complet-d by 15 Mar 79. It will now have to be rescheduled after discussions with WES.

d. Subtask 4 - Six months will be required to complete all tests and analyze data: Completed by 31 Jul 79.

e. Subtask 5 - Submission of technical report: Completed 45 days after completion of Subtask 4, completed by 15 Sep 79.

6. Safety - All pilot containment system operations are to be conducted in accordance with published facility operating procedures.

7. Resources - See Tables 1 and 2.

TABLE 1

RESOURCE PLAN - PART 1
RESOURCE ESTIMATE WORKSHEET
(CDIR REG 5-1)

WBS Level/Subtask	Start/Compl Date	Skill (Contam Mig Br)
Subtask 1	On-going	Physical Scientist (GS-11) Phys Sci Tech (GS-5/7) Computer Prog (GS-11/12)
Subtask 2	1 Feb - 1 Mar	Physical Scientist (GS-11) Phys Sci Tech (GS-9)
Subtask 3	Subject to Scheduling Decision	Physical Scientist (GS-11)
Subtask 4	1 Feb - 31 Jul	Physical Scientist (GS-11) Physical Scientist (GS-9) Phys Sci Tech (GS-5/7)
Subtask 5	1 Aug - 15 Sep	Physical Scientist (GS-11)

Direct Labor Hours	Direct Labor $	Materials $	Contract $	Other $	Overhead $	Total
360 [1]	4,626	908	0	810	2,376	8,720
80	1,028	202	0	180	528	1,938
80	1,028	202	10,000	180	528	1,938
586	7,530	1,476	0 [2]	1,319	3,868	14,193
300	3,855	756	0	675	1,980	7,266

1 - Estimated 60 hours per month for duration of Subtask 1.
2 - In-house drilling assets would be used to drill monitoring wells; if not available, a contract would be used.

TABLE 2

RESOURCE PLAN - PART II
ANNUAL PLAN - CURRENT FY 79
(CDIR REG 5-1)

WBS Level/ Subtask Title	Funds	Feb	Mar	Apr	May	Jun	Jul
Subtask 1							
Current FY							
Obligation	0	0	0	0	0	0	0
Cost	8,720	1,453	1,453	1,453	1,453	1,454	1,454
Manhours	See Table 1	60	60	60	60	60	60
Prior FY							
Obligation	0	0	0	0	0	0	0
Cost	0	0	0	0	0	0	0
Manhours	0	0	0	0	0	0	0
Subtask 2							
Current FY							
Obligation	0	0	0	0	0	0	0
Cost	1,938	1,938	0	0	0	0	0
Manhours	80	80	0	0	0	0	0
Prior FY							
Obligation	0	0	0	0	0	0	0
Cost	0	0	0	0	0	0	0
Manhours	0	0	0	0	0	0	0

TABLE 2, RESOURCE PLAN - PART II - Cont

	Funds	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Subtask 3									
Current FY									
Obligation	0	0	0	0	0	0	0	0	0
Cost	1.938	0	1,938	0	0	0	0	0	0
Manhours	80	0	80	0	0	0	0	0	0
Prior FY									
Obligation	0	0	0	0	0	0	0	0	0
Cost	0	0	0	0	0	0	0	0	0
Manhours									
Subtask 4									
Current FY									
Obligation	0	0	0	0	0	0	0	0	0
Cost	14,193	339	581	581	1,066	5,813	5,813	0	0
Manhours	342	14	24	24	44	240	240	0	0
Prior FY									
Obligation	0	0	0	0	0	0	0	0	0
Cost	0	0	0	0	0	0	0	0	0
Manhours	0	0	0	0	0	0	0	0	0
Subtask 5									
Current FY									
Obligation	0	0	0	0	0	0	0	0	0
Cost	7,266	0	0	0	0	0	0	4,844	2,422
Manhours	300	0	0	0	0	0	0	200	100
Prior FY									
Obligation	0	0	0	0	0	0	0	0	0
Cost	0	0	0	0	0	0	0	0	0
Manhours	0	0	0	0	0	0	0	0	0

WORK STATEMENT

1. Objective - Evaluate the effectiveness of a hydrologic extension to the existing north boundary containment system.

2. Tasks

a. Determine if a hydrologic extension can be successfully operated. Successful operation of the extension is defined as: (1) Removal of pollutants (list to be provided) from water leaving the Arsenal so that the water meets applicable drinking water standards and (2) The off-post water regime is not adversely altered.

b. Provide the following information about the hydrologic system, if it can be successfully operated as follows:

(1) Optimum spacing between dewatering wells.

(2) Optimum spacing between recharge system subunits (e.g., wells) .

(3) Best spacing between dewatering system and recharge system.

(4) Position of the hydrologic extension in relation to the north Arsenal boundary.

c. Determine the need for a westward extension to the existing containment system. If a westward extension is determined to be required, determine if a hydrologic extension can be successfully installed. Provide a brief description of this proposed extension.

d. Compare construction and operating costs for the hydrologic and physical barrier configurations over a 5, 10, 15, 20, and 25 year operational time frame. The cost analysis will address all costs associated with a system such as construction materials, construction costs, cost of anticipated repairs/replacement items, system upkeep costs, personnel operating costs, projected inflation-caused increases, overhead or other indirect costs, and utilities costs. If needed, the westward extension must also be included in the economic analysis.

3. Guidelines

a. The existing pollutant treatment facility (Calgon facility) can be used only if its capacity would not be exceeded by the proposed extension to the containment system. If exceeded, costs associated with expanding the Calgon facility must be included in the economic analysis.

APPENDIX 2

b. Evaluate the effectiveness of the hydrologic extension for two eastward lengths, approximately 2,000 feet and 3,300 feet. The first distance intercepts the plume of polluted groundwater leaving the Arsenal; the second distance additionally extends across First Creek.

4. Period of Performance - Mar and Apr 79.

5. Reporting Requirements - Two copies of a final report will be provided to the COTR by 1 May 79.

6. Estimated Cost

a. Personnel - $7,500.

b. Travel - $1,500.

c. Miscellaneous - $950.

d. Total Estimated Cost - $9,950.

7. COTR - Dr. John F. Wardell, Contamination Migration Branch, Technical Operations Directorate, RMA, Commerce City, Colorado 80022, Telephone: 303-288-0711, Ext 366/367.